JC10 Rec'd PCT/PTC 13 MAR 2002

FORM PTO-1390 (Modified) (REV 11-2000) U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE		ATTORNEY'S DOCKET NUMBER 112740-531
TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371		U.S. APPLICATION NO. (IF KNOWN, SEE 37 CFR 10/088131
INTERNATIONAL APPLICATION NO. **PCT/DE00/03106**	INTERNATIONAL FILING DATE **07 September 2000**	PRIORITY DATE CLAIMED **13 September 1999**

TITLE OF INVENTION
METHOD AND SYSTEM FOR SYNCHRONIZATION OF BASE STATIONS IN A MOBILE COMMUNICATIONS NETWORK

APPLICANT(S) FOR DO/EO/US
Juergen Heitmann

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☒ This is an express request to begin national examination procedures (35 U.S.C. 371(f)). The submission must include itens (5), (6), (9) and (24) indicated below.
4. ☒ The US has been elected by the expiration of 19 months from the priority date (Article 31).
5. ☒ A copy of the International Application as filed (35 U.S.C. 371 (c) (2))
   - a. ☒ is attached hereto (required only if not communicated by the International Bureau).
   - b. ☐ has been communicated by the International Bureau.
   - c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☒ An English language translation of the International Application as filed (35 U.S.C. 371(c)(2)).
   - a. ☒ is attached hereto.
   - b. ☐ has been previously submitted under 35 U.S.C. 154(d)(4).
7. ☒ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371 (c)(3))
   - a. ☐ are attached hereto (required only if not communicated by the International Bureau).
   - b. ☒ have been communicated by the International Bureau.
   - c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
   - d. ☐ have not been made and will not be made.
8. ☒ An English language translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. ☒ An oath or declaration of the inventor(s) (35 U.S.C. 371 (c)(4)).
10. ☐ An English language translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371 (c)(5)).
11. ☒ A copy of the International Preliminary Examination Report (PCT/IPEA/409).
12. ☒ A copy of the International Search Report (PCT/ISA/210).

Items 13 to 20 below concern document(s) or information included:

13. ☒ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
14. ☒ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
15. ☒ A **FIRST** preliminary amendment.
16. ☐ A **SECOND** or **SUBSEQUENT** preliminary amendment.
17. ☒ A substitute specification.
18. ☐ A change of power of attorney and/or address letter.
19. ☐ A computer-readable form of the sequence listing in accordance with PCT Rule 13ter.2 and 35 U.S.C. 1.821 - 1.825.
20. ☐ A second copy of the published international application under 35 U.S.C. 154(d)(4).
21. ☐ A second copy of the English language translation of the international application under 35 U.S.C. 154(d)(4).
22. ☒ Certificate of Mailing by Express Mail
23. ☐ Other items or information:

JC13 Rec'd PCT/PTO 13 MAR 2002

U.S. APPLICATION NO. (IF KNOWN, SEE 37 CFR	INTERNATIONAL APPLICATION NO.	ATTORNEY'S DOCKET NUMBER
10/088151	PCT/DE00/03106	112740-531

24. The following fees are submitted:.

	CALCULATIONS	PTO USE ONLY
BASIC NATIONAL FEE (37 CFR 1.492 (a) (1) - (5)) :		
☐ Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO **$1040.00**		
☒ International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO **$890.00**		
☐ International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO **$740.00**		
☐ International preliminary examination fee (37 CFR 1.482) paid to USPTO but all claims did not satisfy provisions of PCT Article 33(1)-(4) **$710.00**		
☐ International preliminary examination fee (37 CFR 1.482) paid to USPTO and all claims satisfied provisions of PCT Article 33(1)-(4) **$100.00**		
ENTER APPROPRIATE BASIC FEE AMOUNT =	**$890.00**	
Surcharge of **$130.00** for furnishing the oath or declaration later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492 (e)).	**$0.00**	

CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE		
Total claims	23 - 20 =	3	x $18.00	**$54.00**	
Independent claims	2 - 3 =	0	x $84.00	**$0.00**	
Multiple Dependent Claims **(check if applicable).**			☐	**$0.00**	
TOTAL OF ABOVE CALCULATIONS =				**$944.00**	
☐ Applicant claims small entity status. See 37 CFR 1.27). The fees indicated above are reduced by 1/2.				**$0.00**	
SUBTOTAL =				**$944.00**	
Processing fee of **$130.00** for furnishing the English translation later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492 (f)). +				**$0.00**	
TOTAL NATIONAL FEE =				**$944.00**	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31) **(check if applicable).** ☐				**$0.00**	
TOTAL FEES ENCLOSED =				**$944.00**	
				Amount to be: refunded	$
				charged	$

a. ☒ A check in the amount of **$944.00** to cover the above fees is enclosed.

b. ☐ Please charge my Deposit Account No. ________ in the amount of ________ to cover the above fees. A duplicate copy of this sheet is enclosed.

c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. **02-1818** A duplicate copy of this sheet is enclosed.

d. ☐ Fees are to be charged to a credit card. **WARNING:** Information on this form may become public. **Credit card information should not be included on this form.** Provide credit card information and authorization on PTO-2038.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO:

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SIGNATURE

William E. Vaughan
NAME

39,056
REGISTRATION NUMBER

March 13, 2002
DATE

BOX PCT

IN THE UNITED STATES ELECTED/DESIGNATED OFFICE
OF THE UNITED STATES PATENT AND TRADEMARK OFFICE
UNDER THE PATENT COOPERATION TREATY-CHAPTER II

PRELIMINARY AMENDMENT

APPLICANT:	Juergen Heitmann	DOCKET NO: 112740-531
SERIAL NO:		GROUP ART UNIT:
		EXAMINER:
INTERNATIONAL APPLICATION NO:		PCT/DE00/03106
INTERNATIONAL FILING DATE:		07 September 2000
INVENTION:	METHOD AND SYSTEM FOR SYNCHRONIZATION OF BASE STATIONS IN A MOBILE COMMUNICATIONS NETWORK	

Assistant Commissioner for Patents,
Washington, D.C. 20231

Sir:

Please amend the above-identified International Application before entry into the National stage before the U.S. Patent and Trademark Office under 35 U.S.C. §371 as follows:

In the Specification:

Please replace the Specification of the present application, including the Abstract, with the following Substitute Specification:

SPECIFICATION

TITLE OF THE INVENTION

METHOD AND SYSTEM FOR SYNCHRONIZATION OF BASE STATIONS IN A MOBILE COMMUNICATIONS NETWORK

BACKGROUND OF THE INVENTION

In many communications systems, terminals which may be used for different purposes, such as for transmitting voice, video, fax, multimedia, information, text, program and/or measurement data, are increasingly being connected without the use of wires. A connection to such mobile terminals is normally produced via so-called base stations which are connected to a communications network and can be connected to the mobile terminals via an air interface. In the following text, the expression mobile terminals should be understood also as meaning so-called cordless terminals.

User data is generally interchanged via the air interface between a mobile terminal and a base station within time frames which are predetermined by a clock, and which are referred to in the following text as radio time frames.

The area around a base station in which a wire-free connection of predetermined quality can be set up between a mobile terminal and this base station is also referred to as the radio cell of this base station. In order to supply a larger area with connection capabilities, a number of base stations are generally distributed over the area to be supplied, such that their radio cells form a radio network covering the entire area. A mobile terminal which is registered in such a radio network can, in this case, move in any desired way between each of the base stations which are located within radio range in this radio network. The process of a mobile terminal being passed on from a first base station to a second base station while a connection exists is also referred to as a handover. In general, such a change in the connection profile should take place as far as possible without any perceptible interruption in the connection. This is also referred to as a seamless handover.

However, to carry out a seamless handover, the base stations involved must be synchronized to one another with respect to the air interface. For example, user data to be transmitted via a DECT air interface is embedded in radio time frames whose starts in the base stations involved in a seamless handover must not differ from one another by more than 2 μs.

In this context, the expression synchronization of base stations should be understood as meaning, in particular, synchronization of radio time frames, on which a user data interchange with mobile terminals is based, from different base stations.

Laid-open Specification WO 96/38990 discloses a mobile communications system, in which base stations are each connected to a private branch exchange via an S_0 interface in accordance with the ISDN Standard. In this case, a reference clock is transmitted from the private branch exchange to the base stations via the S_0 interface on the physical layer of the transmission protocol that is being used. The clock generators in these base stations are synchronized on the basis of the reference clock, which is received in the same way by all the base stations.

With regard to the increasing networking of communications systems, increasing integration of voice and data services, and increasing use of complex service features by mobile terminals, it is being found that the connection of base stations via S_0 interfaces is too inflexible. The lack of flexibility is a result, in particular, of the transmission of the reference clock in the physical layer of the transmission protocol that is being used, since continuous layer 1 connections between the private branch exchange system and the base stations are required for this purpose.

An object of the present invention is to specify a method and a system which is more flexible than the prior art for synchronization of base stations in a mobile communications network, in particular for the purpose of a seamless handover.

SUMMARY OF THE INVENTION

In order to synchronize base stations in a mobile communications network with respect to their air interface, time information is transmitted to the base

stations via a local area network; for example, from a time information server. These base stations are synchronized to one another by each aligning their own time measure to time information that is received.

The local area network, which is frequently referred to as a LAN, can be implemented in many ways; for example, in the form of Ethernet, Token Ring, Token Bus or FDDI. The present invention allows base stations to be synchronized with little effort, even in complex mobile communications networks. In particular, base stations easily can be integrated in local computer networks, in which case an existing network infrastructure can be used for synchronization. A connection from base stations in a mobile communications network to a local area network is particularly advantageous with respect to increasing integration of voice and data communication, as well.

One major aspect of the present invention is the fact that transmission of time information via a local area network is particularly highly suitable for synchronization of base stations for the purpose of the seamless handover. Since only mutually adjacent base stations are essentially involved in a handover process, only the radio time frames of adjacent base stations need be synchronized to one another with high accuracy at the time of the handover, as well. The present invention now makes it possible to achieve a high level of synchronization accuracy, especially for mutually adjacent base stations, since, in the case of adjacent base stations, both the propagation times of time information to the respective base station and the propagation time fluctuations differ only slightly.

According to one advantageous embodiment of the present invention, the clock transmitter in a base station can be adjusted by readjusting its clock frequency and/or phase. In order to avoid abrupt changes in the clock frequency and/or phase, an appropriate control signal can be passed via an integration element to the clock transmitter. As an alternative to this, a clock transmitter error also can be corrected by inserting or omitting clock pulses.

According to another advantageous embodiment of the present invention, time information can be requested by a base station via the local area network from a time information server. The request can, in this case, be made using known

network protocols, such as the so-called network time protocol (NTP) or the so-called digital time synchronization protocol (DTSS).

In order to improve the accuracy of the time information which is obtained, the time difference between the request for and the reception of time information can be measured, in order to determine from this an estimated value for the propagation time of the time information from the time information server to the relevant base station.

On the assumption that the propagation time of the request approximately matches the propagation time of the time information, the propagation time of the time information is half the measured time difference. The accuracy of the estimated value for the propagation time of time information can be improved by determining the estimated value from a mean value of time differences measured over a number of requests, or of variables derived from them. This makes it possible to compensate for propagation time fluctuations in the data transmitted via the local area network. The determined estimated value for the propagation time of time information can be taken into account to correct the adjustment of the clock transmitter.

The frequency with which time information is requested by a base station may depend on various criteria; for example, on the accuracy of the clock transmitter in the base station, on the variation range of the time differences measured between a request for and reception of time information, and/or on the magnitude of any clock transmitter error that was found in a previous adjustment of the clock transmitter. The time information preferably can be requested more frequently the less the accuracy of the clock transmitter and the greater the variation range of the measured time differences and the error that is found in the clock transmitter.

According to a further advantageous embodiment of the present invention, a data stream which is received via the local area network can be buffered in an input buffer store operating on the first-in-first-out principle (FIFO), from which data elements of the data stream are read for further processing using a clock cycle

governed by the clock transmitter. The clock frequency of the clock transmitter then can be readjusted on the basis of the filling level of the input buffer store.

Subject to the precondition that the data stream received via the local area network is transmitted, at least when averaged over time, at a data rate which is predetermined by a clock transmitter in the data stream transmitter, the clock transmitter in the base station can be synchronized to the clock transmitter in the data stream transmitter when averaged over time. In order to compensate for short-term propagation time fluctuations of data elements in the data stream, a clock frequency control signal, which is derived from the filling level, can be passed to the clock transmitter via an integration element.

A data stream of communications data which is received via the local area network and is to be transmitted to a mobile terminal, such as voice data, can be used for clock frequency control. Since communications data and, in particular, voice data is transmitted frequently in an existing connection at a transmission rate which is maintained accurately and is based on the time clock for the transmitter of the communications data, the clock frequency of the clock transmitter can be stabilized particularly accurately on the basis of received communications data or voice data.

Additional features and advantages of the present invention are described in, and will be apparent from, the following Detailed Description of the Invention and the Figures.

BRIEF DESCRIPTION OF THE FIGURES

Figure 1 shows a mobile communications network with two base stations which are connected to a switching device via a local area network.

Figure 2 shows a detailed illustration of one of the base stations which are connected to the local area network.

DETAILED DESCRIPTION OF THE INVENTION

Figure 1 illustrates, schematically, a mobile communications network with a switching device VE, which is connected to a landline network FN, and with two base stations BS1 and BS2, which are coupled to the switching device VE via a local area network LAN. In the present exemplary embodiment, the base stations

BS1 and BS2 are in the form of DECT base stations (Digital European Cordless Telephone). While a wire-free connection is set up via the base station BS1 to a mobile terminal EG1, a wire-free connection to a mobile terminal EG2 runs via the base station BS2. The mobile terminal EG1 is also connected by radio to the base station BS2, which is adjacent to the base station BS1, in order to prepare for a change in the connection routing (handover) from the base station BS1 to the base station BS2. The radio links are each indicated by a stylized lightning flash in the present exemplary embodiment.

The switching device VE is connected to the landline network FN via a landline network interface FNS, and is connected to the local area network LAN via a network interface NS. The switching device VE also has a central controller ZS, which is connected to the network interfaces FNS and NS and has a real-time clock RTC, and also has a GPS (Global Positioning System) receiver GPS for receiving world time information from a satellite SAT. The real-time clock RTC is adjusted by the GPS receiver by the transmission of up-to-date time information ZI at regular time intervals.

The local area network LAN which may, for example, be an Ethernet, Token Ring, Token Bus or FDDI, supports packet-oriented data transmission. In addition to communications devices, data processing devices (not shown) also can be connected to the local area network LAN. In the present exemplary embodiment, the local area network LAN is used for transmitting not only all the communications data but also all the control data between the switching device VE and the base stations BS1 and BS2. Since a local area network can be extended very easily and can very easily have further communications and/or data processing devices added to it, a mobile communications network implemented in such a way can be matched very flexibly to widely differing requirements.

In the present exemplary embodiment, communications data KD1 and KD2, such as voice data, is transmitted from the landline network FN to the switching device VE via connections which lead from the landline network FN to the mobile terminals EG1 and EG2. In this switching device VE, the communications data KD1, KD2 which has been received via the landline network interface FNS is, in

each case, provided by the central controller ZS with address information to identify the base station BS1 or BS2 in the local area network LAN, and is transmitted via the network interface NS to the local area network LAN. The base stations BS1 and BS2 receive from the local area network LAN the respective communications data addressed to them themselves; that is to say, the base station BS1 receives the communications data KD1, and the base station BS2 receives the communications data KD2. The base stations BS1 and BS2, respectively, then transmit the received communications data KD1 and KD2, respectively, embedded in DECT time frames, without wires to the mobile terminals EG1 and EG2, respectively.

In order to allow a seamless handover during an existing connection for a mobile terminal, in this case EG1, between two adjacent base stations, in this case BS1 and BS2, these base stations BS1 and BS2 have to maintain a frequency accuracy of $\pm\ 10^{-3}\%$ in accordance with the DECT Standard. Furthermore, the DECT time frames, on which data transmission to a mobile terminal is based, in the base stations BS1 and BS2 must be synchronized to one another with a tolerance of 2 μs. In order to synchronize the base stations BS1 and BS2 to one another, each of the base stations BS1 and BS2 is synchronized in its own right to a central clock transmitter device, in this case the real-time clock RTC in the switching device VE. The synchronization process is carried out via the local area network LAN. For this purpose, the base stations BS1 and BS2 each transmit a time request message ZA1 or ZA2, respectively, in accordance with the so-called network time protocol (NTP), for example, via the local area network LAN to the switching device VE. The received time request messages ZA1, ZA2 in each case cause the switching device VE to request up-to-date time information ZI1 or ZI2, respectively, from the real-time clock RTC, and then to transmit it, together with address information identifying the respective base station BS1 or BS2, via the local area network LAN to the respectively addressed base station BS1 or BS2. The switching device VE thus carries out the function of a time information server in the local area network LAN.

Figure 2 shows a more detailed illustration of the base station BS1. The base station BS1, which is coupled via a network interface NS to the local area network LAN, has, as further functional components, a receiving device EE, an input buffer store EP, a clock transmitter ZTG, a clock adjustment device ZJ, a frequency controller FS, and a DECT radio section DECT. The clock adjustment device ZJ itself has an internal clock CLK, a propagation time determination device LB, a propagation time correction device LK and an integration element IG. For reasons of clarity, the illustration does not show the other functional components of the base station BS1 which do not contribute directly to understanding of the present invention. The illustrated functional components each may be in the form of software modules running on a system processor in the base station BS1.

The clock transmitter ZTG thus provides not only a bit clock BT but also a frame clock RT synchronized to it. The frequency of the bit clock BT and, hence, the frequency of the frame clock RT, are in this case controllable. While the bit clock BT represents the elementary time measure for the control processes in the base station BS1, the frame clock RT provides a time measure for the DECT time frames. In the present exemplary embodiment, the bit clock BT is supplied to the clock adjustment device ZJ, to the input buffer store EP and to the DECT radio section DECT. In the clock adjustment device ZJ, the bit clock BT is used, in particular, for supplying timing pulses to the internal clock CLK. The DECT radio section DECT is supplied not only with the bit clock BT but also with the frame clock RT, which governs the time pattern for the DECT time frames transmitted by the DECT radio section DECT.

In order to synchronize the clock transmitter ZTG to the time measure in the switching device VE, the clock adjustment device ZJ transmits the time request message ZA1 via the network interface NS and via the local area network LAN to the switching device VE. The time at which the time request message ZA1 is transmitted is, in this case, registered and stored via the internal clock CLK. The time request message ZA1 causes the switching device VE, as already mentioned above, to transmit the time information ZI1 via the local area network LAN to the base station BS1. The time information ZI1 is passed on from the network

interface NS for the base station BS1 to the receiving device EE, where the time information ZI1 is extracted from a data stream which is received via the local area network LAN and also contains the communications data KD1. The extracted time information ZI1 is passed on from the receiving device EE to the clock adjustment device ZJ, which uses the internal clock CLK to determine the time at which the time information ZI1 is received, and evaluates the time information content of the time information ZI1. The propagation time determination device LB then estimates the propagation time of the time information ZI1 in the local area network LAN as being half the time difference between the time at which it was found that the time information ZI1 was received and the stored transmission time of the time request message ZA1.

In order to improve the accuracy of determining the propagation time and to compensate for short-term propagation time fluctuations, the value which is obtained for the propagation time is averaged together with previously determined values for the propagation time. A sliding average is preferably determined. If required, a time stamp relating to the time information ZI1 also can be included in the propagation time determination process.

The time indicated by the time information content of the time information ZI1 is then corrected by the propagation time correction device LK for the previously determined propagation time of the time information ZI1. The corrected time is then compared with the time indicated by the internal clock CLK for the time at which the time information ZI1 was received. Depending on the comparison result, a frequency control signal FRS is then formed in order to control the clock frequency of the clock generator ZTG. The frequency control signal FRS is emitted from the clock adjustment device ZJ via the time integration element IG, whose time constant is designed so as to compensate for the typical propagation time fluctuations that occur in the local area network LAN.

If comparatively major discrepancies occur between the internal clock CLK and the real-time clock RTC in the switching device VE, the clock adjustment device ZJ preferably can request time information from the switching device VE at shorter time intervals.

In the time intervals between each occasion on which time information is received, the clock frequency of the clock transmitter ZTG is stabilized via the communications data KD1, which likewise is received via the local area network LAN. The communications data KD1 is, for this purpose, supplied from the receiver device EE to the input of the input buffer store EP. This is in the form of a so-called first-in-first-out store, from which temporarily stored data is read in the same time sequence as that in which it was stored. A first-in-first-out store or memory is also often referred to as a "FIFO". The communications data KD1 that has been temporarily stored in the input buffer store EP is read from this buffer store on the basis of the bit clock BT supplied from the clock transmitter ZTG, and is supplied to the DECT radio section DECT. Finally, from there, the communications data KD1 is transmitted without wires to the mobile terminal EG1.

As a rule, communications data and, in particular, voice data is transmitted from a switching device to a terminal at a constant data rate, which is based strictly on the clock in the switching device. Despite any propagation time fluctuations to which such communications data which is transmitted at a constant data rate may be subject, this communications data arrives at the receiver at the same data rate, at least when averaged over time. The time average of the data rate from the received communications data is thus used to synchronize a receiver of such communications data with the clock in the transmitter.

In the present exemplary embodiment, communications data KD1, KD2 is transmitted from the switching device VE at a constant data rate and is used by the base stations BS1, BS2 to stabilize the clock frequency of its own clock transmitter ZTG during the time intervals between individual checks of the time information. For this purpose, in the base station BS1, the present filling level of the input buffer store EP, or the limit up to which the input buffer store EP is filled with communications data KD1, is recorded at regular time intervals and is transmitted in the form of filling level information FI to the frequency controller FS. The frequency controller FS uses the filling level information FI to form a frequency control signal FRS, which is emitted via an integration element IG, and is combined with the frequency control signal formed by the clock adjustment device

ZJ in order to control the clock frequency of the clock transmitter ZTG. The time constant of the integration element IG in the frequency controller FS is designed so as to compensate for the typical propagation time fluctuations of the communications data KD1 which occur in the local area network LAN. For example, the integration elements IG in the frequency controller FS and in the clock adjustment device ZJ may be in the form of a digital circuit in order to form sliding mean values. If the filling level of the input buffer store EP is greater than average, the frequency controller FS forms a frequency control signal FRS in order to increase the clock frequency of the clock generator ZTG, while, if the filling level of the input buffer store EP is below average, it forms a frequency control signal in order to reduce the clock frequency. The frequency control signals FRS emitted from the clock adjustment device ZJ and from the frequency controller FS each can be combined with predetermined weighting factors before being supplied to the clock transmitter ZTG. In this case, the frequency control signal FRS formed by the clock adjustment device ZJ is preferably given a higher weighting than that formed by the frequency controller FS. The additional stabilization of the clock frequency of the clock transmitter ZTG on the basis of the filling level of the input buffer store EP also allows a relatively low-cost crystal generator without any complex temperature stabilization to be used as the clock transmitter ZTG, in order to ensure synchronization even if the time intervals between individual time checks are comparatively long.

Although the transmission of the time information ZI1, ZI2 and of the communications data KD1, KD2 via the local area network LAN is not time-transparent, the present invention allows adjacent base stations BS1 and BS2 to be synchronized with sufficient accuracy for seamless handover processes. The high synchronization accuracy is assisted, in particular, by the fact that both the propagation times and the propagation time fluctuations of time information ZI1, ZI2 and communications data KD1, KD2 differ only slightly for adjacent base stations.

In the present exemplary embodiment, the synchronization accuracy is also increased by the use of a number of frequency control mechanisms, and the compensation for propagation time fluctuations via the integration elements IG.

In order to ensure the synchronization accuracy between the base stations BS1 and BS2 which is required for a seamless handover, even in relatively large local area networks LAN, network elements of the local area network LAN, such as repeaters and/or routers, are arranged such that the respective number of network elements connected between the switching device VE and the respective base station BS1 or BS2, and connected between the base station BS1 and BS2, is not greater than a respectively predetermined number.

Although the present invention has been described with reference to specific embodiments, those of skill in the art will recognize that changes may be made thereto without departing from the spirit and scope of the invention as set forth in the hereafter appended claims.

ABSTRACT OF THE DISCLOSURE

Method and system for synchronization of base stations in a mobile communications network, in particular for the purpose of a seamless handover, time information is transmitted, possibly on request, to the base stations from a time information server via a local area network. Since base stations which are involved in a seamless handover are generally adjacent, and the respective propagation times and/or propagation time fluctuations of time information differ only slightly in the local area network between the time information server and the base station when the base stations are adjacent, highly accurate synchronization may be achieved, especially for a seamless handover.

In the claims:

On page 15, cancel line 1, and substitute the following left-hand justified heading therefor:

CLAIMS

Please cancel claims 1-23, without prejudice, and substitute the following claims therefor:

24. A method for synchronization of base stations in a mobile communications network, the method comprising the steps of:

transmitting time information via a packet-oriented local area network to the base stations;

adjusting a clock transmitter for a respective base station which receives the time information based on reception time and time information content of the time information; and

controlling transmission of functional sequences, which relate to radio time frames, to the respective base station by signals from the clock transmitter.

25. A method for synchronization of base stations in a mobile communications network as claimed in claim 24, wherein the step of adjusting the clock transmitter includes readjusting one of a frequency and a phase of the clock transmitter.

26. A method for synchronization of base stations in a mobile communications network as claimed in claim 24, wherein the step of adjusting the clock transmitter includes one of omitting and inserting clock pulses.

27. A method for synchronization of base stations in a mobile communications network as claimed in claim 24, the method further comprising the step of requesting the time information by the respective base station via the local area network from a time information server.

28. A method for synchronization of base stations in a mobile communications network as claimed in claim 27, the method further comprising the step of employing a standardized network protocol for the steps of requesting and transmitting the time information.

29. A method for synchronization of base stations in a mobile communications network as claimed in claim 27, the method further comprising the steps of:

measuring a time difference between the request for and a reception of the time information;

determining an estimated value for propagation time of the time information from the time information server to the respective base station from the measured time difference; and

adjusting the clock transmitter using the determined estimated value of propagation time of the time information.

30. A method for synchronization of base stations in a mobile communications network as claimed in claim 29, wherein the step of measuring the time difference is performed via the clock transmitter in the respective base station.

31. A method for synchronization of base stations in a mobile communications network as claimed in claim 29, wherein the step of determining the estimated value for propagation time of the time information includes one of averaging over a plurality of measured time differences and averaging over a plurality of variables defined from the plurality of measured time differences.

32. A method for synchronization of base stations in a mobile communications network as claimed in claim 27, wherein the time information is requested by the respective base station at regular time intervals via the local area network.

33. A method for synchronization of base stations in a mobile communications network as claimed in claim 29, wherein the time information is requested by the respective base station via the local area network at time intervals which are dependent on a severity with which the measured time differences vary.

34. A method for synchronization of base stations in a mobile communications network as claimed in claim 24, the method further comprising the steps of:

temporarily storing a data stream, which is received via the local area network from a base station, in an input buffer store which operates on a first-in-first-out principle;

reading data elements from the data stream for further processing using a clock cycle governed by the clock transmitter;

recording a filling level over the input buffer store; and

readjusting the clock frequency of the clock transmitter based on the recorded filling level.

35. A method for synchronization of base stations in a mobile communications network as claimed in claim 34, wherein the data stream includes communications data to be transmitted to a mobile terminal.

36. A method for synchronization of base stations in a mobile communications network as claimed in claim 34, wherein the adjustment of the clock transmitter based on the received time information is given priority over the adjustment of the clock transmitter based on the recorded filling level.

37. A method for synchronization of base stations in a mobile communications network as claimed in claim 24, wherein time information from a plurality of time information servers is received by the respective base station via the local area network and used for adjustment of the clock transmitter.

38. A system for synchronization of base stations in a mobile communications network, comprising:

a packet-oriented local area network; and

a plurality of base stations coupled to the local area network, wherein each of the base stations includes parts for synchronization of a time measure for the respective base station based on time information which is transmitted via the local area network.

39. A system for synchronization of base stations in a mobile communications network as claimed in claim 38, further comprising a time information server, coupled to the local area network, having a timer device for transmitting the time information via the local area network to the base stations, with each of the base stations further including a clock transmitter, a time information receiving device for extracting the time information from a data stream which has been received via the local area network, a clock adjustment device for adjusting a clock transmitter based on reception time and time information content of the received time information, and a control device for controlling timing of functional sequences, which relate to transmission of radio timeframes, based on signals from the clock transmitter.

40. A system for synchronization of base stations in a mobile communications network as claimed in claim 39, wherein the time information server includes a satellite navigation receiver device for receiving world time information and for presetting a time measure for the time information server based on the received world time information.

41. A system for synchronization of base stations in a mobile communications network as claimed in claim 39, wherein each of the base stations further includes a time checking device for requesting the time information via the local area network.

42. A system for synchronization of base stations in a mobile communications network as claimed in claim 41, wherein each of the base stations further includes a time measurement device for measuring a time difference between a request for and reception of the time information, a propagation time determination device for determining an estimated value of propagation time of the time information from the time information server to the respective base station based on the measured time difference, and a propagation time correction device for correcting the time information for its estimated propagation time.

43. A system for synchronization of base stations in a mobile communications network as claimed in claim 42, wherein the time measurement device is a counter which counts signals from the clock transmitter.

44. A system for synchronization of base stations in a mobile communications network as claimed in claim 39, wherein each of the base stations further includes an input buffer store for temporarily storing a data stream which is received via the local area network, a filling level recording device for recording a filling level of the input buffer store, and a clock frequency control device for readjusting a clock frequency of the clock transmitter as a function of the recorded filling level.

45. A system for synchronization of base stations in a mobile communications network as claimed in claim 39, wherein each of the base stations further includes a PLL circuit for controlling a clock frequency of the clock transmitter.

46. A system for synchronization of base stations in a mobile communications network as claimed in claim 38, wherein the base stations are adjacent in the local area network.

REMARKS

The present amendment makes editorial changes and corrects typographical errors in the specification, which includes the Abstract, in order to conform the specification to the requirements of United States Patent Practice. No new matter is added thereby. Attached hereto is a marked-up version of the changes made to the specification by the present amendment. The attached page is captioned **"Version With Markings To Show Changes Made".**

In addition, the present amendment cancels original claims 1-23 in favor of new claims 24-46. Claims 24-46 have been presented solely because the revisions by crossing out and underlining which would have been necessary in claims 1-23 in order to present those claims in accordance with preferred United States Patent Practice would have been too extensive, and thus would have been too burdensome. The present amendment is intended for clarification purposes only and not for substantial reasons related to patentability pursuant to 35 U.S.C. §§101, 102, 103 or 112. Indeed, the cancellation of claims 1-23 does not constitute an intent on the part of the Applicants to surrender any of the subject matter of claims 1-23.

Early consideration on the merits is respectfully requested.

Respectfully submitted,

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Version With Markings To Show Changes Made

~~Description~~ SPECIFICATION

~~Method and arrangement for synchronization of base stations in a mobile communications network~~

TITLE OF THE INVENTION

METHOD AND SYSTEM FOR SYNCHRONIZATION OF BASE STATIONS IN A MOBILE COMMUNICATIONS NETWORK

BACKGROUND OF THE INVENTION

In many communications systems, terminals which may be used for different purposes, ~~for example~~ such as for transmitting voice, video, fax, multimedia, information, text, program and/or measurement data, are increasingly being connected without the use of wires. A connection to such mobile terminals is normally produced via so-called base stations which are connected to a communications network and can be connected to the mobile terminals via an air interface. In the following text, the expression mobile terminals should ~~also~~ be understood also as meaning so-called cordless terminals.

User data is generally interchanged via the air interface between a mobile terminal and a base station within time frames which are predetermined by a clock, and which are ~~also~~ referred to in the following text as radio time frames.

The area around a base station in which a wire-free connection of predetermined quality can be set up between a mobile terminal and this base station is also referred to as the radio cell of this base station. In order to supply a larger area with connection capabilities, a number of base stations are generally distributed over the area to be supplied, such that their radio cells form a radio network covering the entire area. A mobile terminal which is registered in such a radio network can, in this case, move in any desired way between each of the base stations which are located within radio range in this radio network. The process of a mobile terminal being passed on from a first base station to a second base station while a connection exists is also referred to as a handover. In general, such a change in the connection profile should take place as far as possible without any

perceptible interruption in the connection. This is also referred to as a seamless handover.

However, to carry out a seamless handover, the base stations involved must be synchronized to one another with respect to the air interface. For example, user data to be transmitted via a DECT air interface is embedded in radio time frames whose starts in the base stations involved in a seamless handover must not differ from one another by more than 2 μs.

In this context, the expression synchronization of base stations should be understood as meaning, in particular, synchronization of radio time frames, on which a user data interchange with mobile terminals is based, from different base stations.

Laid-open Specification WO 96/38990 discloses a mobile communications system, in which base stations are each connected to a private branch exchange via an S_0 interface in accordance with the ISDN Standard. In this case, a reference clock is transmitted from the private branch exchange to the base stations via the S_0 interface on the physical layer of the transmission protocol that is being used. The clock generators in these base stations are synchronized on the basis of the reference clock, which is received in the same way by all the base stations.

With regard to the increasing networking of communications systems, increasing integration of voice and data services, and increasing use of complex service features by mobile terminals, it is~~, however,~~ being found that the connection of base stations via S_0 interfaces is too inflexible. The lack of flexibility is a result, in particular, of the transmission of the reference clock in the physical layer of the transmission protocol that is being used, since continuous layer 1 connections between the private branch exchange system and the base stations are required for this purpose.

~~One~~ <u>An</u> object of the present invention is to specify a method <u>and a system</u> which is more flexible than the prior art for synchronization of base stations in a mobile communications network, in particular for the purpose of a seamless handover.

~~Another object is to specify an arrangement for implementing the method.~~

~~This object is achieved by a method having the features of patent claim 1, and by an arrangement having the features of patent claim 15.~~

~~Advantageous embodiments and developments of the invention are specified in the dependent claims.~~

SUMMARY OF THE INVENTION

In order to synchronize base stations in a mobile communications network with respect to their air interface, time information is transmitted to the base stations via a local area network~~,~~; for example, from a time information server. These base stations are synchronized to one another by each aligning their own time measure to time information that is received.

The local area network, which is frequently ~~also~~ referred to as a LAN, can be implemented in many ways~~,~~; for example, in the form of Ethernet, Token Ring, Token Bus or FDDI. The present invention allows base stations to be synchronized with little effort, even in complex mobile communications networks. In particular, base stations ~~can~~ easily can be integrated in local computer networks, in which case an existing network infrastructure can be used for synchronization. A connection from base stations in a mobile communications network to a local area network is particularly advantageous with respect to increasing integration of voice and data communication, as well.

One major aspect of the present invention is the fact that transmission of time information via a local area network is particularly highly suitable for synchronization of base stations for the purpose of the seamless handover. Since only mutually adjacent base stations are essentially involved in a handover process, only the radio time frames of adjacent base stations need be synchronized to one another with high accuracy at the time of the handover, as well. The present invention now makes it possible to achieve a high level of synchronization accuracy, especially for mutually adjacent base stations, since, in the case of adjacent base stations, both the propagation times of time information to the respective base station and the propagation time fluctuations differ only slightly.

According to one advantageous embodiment of the present invention, the clock transmitter in a base station can be adjusted by readjusting its clock

frequency and/or phase. In order to avoid abrupt changes in the clock frequency and/or phase, an appropriate control signal can be passed via an integration element to the clock transmitter. As an alternative to this, a clock transmitter error ~~can~~ also can be corrected by inserting or omitting clock pulses.

According to ~~one~~ another advantageous ~~development~~ embodiment of the present invention, time information can be requested by a base station via the local area network from a time information server. The request can, in this case ~~preferably~~, be made using known network protocols, such as the so-called network time protocol (NTP) or the so-called digital time synchronization protocol (DTSS).

In order to improve the accuracy of the time information which is obtained, the time difference between the request for and the reception of time information can be measured, in order to determine from this an estimated value for the propagation time of the time information from the time information server to the relevant base station.

On the assumption that the propagation time of the request approximately matches the propagation time of the time information, the propagation time of the time information is half the measured time difference. The accuracy of the estimated value for the propagation time of time information can be improved by determining the estimated value from a mean value of time differences measured over a number of requests, or of variables derived from them. This makes it possible to compensate for propagation time fluctuations in the data transmitted via the local area network. The determined estimated value for the propagation time of time information can be taken into account to correct the adjustment of the clock transmitter.

The frequency with which time information is requested by a base station may depend on various criteria~~. For~~; for example, on the accuracy of the clock transmitter in the base station, on the variation range of the time differences measured between a request for and reception of time information, and/or on the magnitude of any clock transmitter error that was found in a previous adjustment of the clock transmitter. The time information ~~can~~ preferably can be requested more frequently the less the accuracy of the clock transmitter and the greater the

variation range of the measured time differences and the error that is found in the clock transmitter.

According to a further advantageous ~~development~~ embodiment of the present invention, a data stream which is received via the local area network can be buffered in an input buffer store operating on the first-in-first-out principle (FIFO), from which data elements of the data stream are read for further processing using a clock cycle governed by the clock transmitter. The clock frequency of the clock transmitter ~~can~~ then can be readjusted on the basis of the filling level of the input buffer store.

Subject to the precondition that the data stream received via the local area network is transmitted, at least when averaged over time, at a data rate which is predetermined by a clock transmitter in the data stream transmitter, the clock transmitter in the base station can ~~thus~~ be synchronized to the clock transmitter in the data stream transmitter~~,~~ when averaged over time. In order to compensate for short-term propagation time fluctuations of data elements in the data stream, a clock frequency control signal, which is derived from the filling level, can be passed to the clock transmitter via an integration element.

A data stream of communications data which is received via the local area network and is to be transmitted to a mobile terminal, such as voice data, can ~~preferably~~ be used for clock frequency control. Since communications data and, in particular, voice data is transmitted frequently in an existing connection at a transmission rate which is maintained accurately and is based on the time clock for the transmitter of the communications data, the clock frequency of the clock transmitter can be stabilized particularly accurately on the basis of received communications data or voice data.

~~An exemplary embodiment of the invention will be explained in more detail in the following text with reference to the drawing.~~

Additional features and advantages of the present invention are described in, and will be apparent from, the following Detailed Description of the Invention and the Figures.

~~In this case, in each case illustrated schematically:~~

BRIEF DESCRIPTION OF THE FIGURES

Figure 1 shows a mobile communications network with two base stations which are connected to a switching device via a local area network~~, and~~.

Figure 2 shows a detailed illustration of one of the base stations which are connected to the local area network.

DETAILED DESCRIPTION OF THE INVENTION

Figure 1 illustrates, schematically, a mobile communications network with a switching device VE, which is connected to a landline network FN, and with two base stations BS1 and BS2, which are coupled to the switching device VE via a local area network LAN. In the present exemplary embodiment, the base stations BS1 and BS2 are in the form of DECT base stations (Digital European Cordless Telephone). While a wire-free connection is set up via the base station BS1 to a mobile terminal EG1, a wire-free connection to a mobile terminal EG2 runs via the base station BS2. The mobile terminal EG1 is also connected by radio to the base station BS2, which is adjacent to the base station BS1, in order to prepare for a change in the connection routing (handover) from the base station BS1 to the base station BS2. The radio links are each indicated by a stylized lightning flash in the present exemplary embodiment.

The switching device VE is connected to the landline network FN via a landline network interface FNS, and is connected to the local area network LAN via a network interface NS. The switching device VE also has a central controller ZS, which is connected to the network interfaces FNS and NS and has a real-time clock RTC, and also has a GPS (Global Positioning System) receiver GPS for receiving world time information from a satellite SAT. The real-time clock RTC is adjusted by the GPS receiver by the transmission of up-to-date time information ZI at regular time intervals.

The local area network LAN which may, for example, be an Ethernet, Token Ring, Token Bus or FDDI, supports packet-oriented data transmission. In addition to communications devices, data processing devices (not shown) ~~can~~ also can be connected to the local area network LAN. In the present exemplary embodiment, the local area network LAN is used for transmitting not only all the

communications data but also all the control data between the switching device VE and the base stations BS1 and BS2. Since a local area network can be extended very easily and can very easily have further communications and/or data processing devices added to it, a mobile communications network implemented in such a way can be matched very flexibly to widely differing requirements.

In the present exemplary embodiment, communications data KD1 and KD2, ~~for example~~ such as voice data, is transmitted from the landline network FN to the switching device VE via connections which lead from the landline network FN to the mobile terminals EG1 and EG2. In this switching device VE, the communications data KD1, KD2 which has been received via the landline network interface FNS is, in each case, provided by the central controller ZS with address information to identify the base station BS1 or BS2 in the local area network LAN, and is transmitted via the network interface NS to the local area network LAN. The base stations BS1 and BS2 receive from the local area network LAN the respective communications data addressed to them themselves; that is to say, the base station BS1 receives the communications data KD1, and the base station BS2 receives the communications data KD2. The base stations BS1 and BS2, respectively, then transmit the received communications data KD1 and KD2, respectively, embedded in DECT time frames, without wires to the mobile terminals EG1 and EG2, respectively.

In order to allow a seamless handover during an existing connection for a mobile terminal, in this case EG1, between two adjacent base stations, in this case BS1 and BS2, these base stations BS1 and BS2 have to maintain a frequency accuracy of $\pm 10^{-3}\%$ in accordance with the DECT Standard. Furthermore, the DECT time frames, on which data transmission to a mobile terminal is based, in the base stations BS1 and BS2 must be synchronized to one another with a tolerance of 2 μs. In order to synchronize the base stations BS1 and BS2 to one another, each of the base stations BS1 and BS2 is synchronized in its own right to a central clock transmitter device, in this case the real-time clock RTC in the switching device VE. The synchronization process is ~~in this case~~ carried out via the local area network LAN. For this purpose, the base stations BS1 and BS2 each transmit a time request

message ZA1 or ZA2, respectively, ~~for example~~ in accordance with the so-called network time protocol (NTP), for example, via the local area network LAN to the switching device VE. The received time request messages ZA1, ZA2 in each case cause the switching device VE to request up-to-date time information ZI1 or ZI2, respectively, from the real-time clock RTC, and then to transmit it, together with address information identifying the respective base station BS1 or BS2, via the local area network LAN to the respectively addressed base station BS1 or BS2. The switching device VE thus carries out the function of a time information server in the local area network LAN.

Figure 2 shows a more detailed illustration of the base station BS1. The base station BS1, which is coupled via a network interface NS to the local area network LAN, has, as further functional components, a receiving device EE, an input buffer store EP, a clock transmitter ZTG, a clock adjustment device ZJ, a frequency controller FS, and a DECT radio section DECT. The clock adjustment device ZJ itself has an internal clock CLK, a propagation time determination device LB, a propagation time correction device LK and an integration element IG. For reasons of clarity, the illustration does not show the other functional components of the base station BS1 which do not contribute directly to understanding of the present invention. The illustrated functional components ~~may~~ each ~~also~~ may be in the form of software modules~~,~~ running on a system processor in the base station BS1.

The clock transmitter ZTG thus provides not only a bit clock BT but also a frame clock RT synchronized to it. The frequency of the bit clock BT~~,~~ and, hence, the frequency of the frame clock RT, are in this case controllable. While the bit clock BT represents the elementary time measure for the control processes in the base station BS1, the frame clock RT provides a time measure for the DECT time frames. In the present exemplary embodiment, the bit clock BT is supplied to the clock adjustment device ZJ, to the input buffer store EP and to the DECT radio section DECT. In the clock adjustment device ZJ, the bit clock BT is used, in particular, for supplying timing pulses to the internal clock CLK. The DECT radio section DECT is supplied not only with the bit clock BT but also with the frame

clock RT, which governs the time pattern for the DECT time frames transmitted by the DECT radio section DECT.

In order to synchronize the clock transmitter ZTG to the time measure in the switching device VE, the clock adjustment device ZJ transmits the time request message ZA1 via the network interface NS and via the local area network LAN to the switching device VE. The time at which the time request message ZA1 is transmitted is, in this case, registered and stored ~~by means of~~ via the internal clock CLK. The time request message ZA1 causes the switching device VE, as already mentioned above, to transmit the time information ZI1 via the local area network LAN to the base station BS1. The time information ZI1 is passed on from the network interface NS for the base station BS1 to the receiving device EE, where the time information ZI1 is extracted from a data stream which is received via the local area network LAN and also contains the communications data KD1. The extracted time information ZI1 is passed on from the receiving device EE to the clock adjustment device ZJ, which uses the internal clock CLK to determine the time at which the time information ZI1 is received, and evaluates the time information content of the time information ZI1. The propagation time determination device LB then estimates the propagation time of the time information ZI1 in the local area network LAN as being half the time difference between the time at which it was found that the time information ZI1 was received and the stored transmission time of the time request message ZA1.

In order to improve the accuracy of determining the propagation time and to compensate for short-term propagation time fluctuations, the value which is obtained for the propagation time is averaged together with previously determined values for the propagation time. A sliding average is preferably determined. If required, a time stamp relating to the time information ZI1 ~~can~~ also can be included in the propagation time determination process.

The time indicated by the time information content of the time information ZI1 is then corrected by the propagation time correction device LK for the previously determined propagation time of the time information ZI1. The corrected time is then compared with the time indicated by the internal clock CLK for the

time at which the time information ZI1 was received. Depending on the comparison result, a frequency control signal FRS is then formed in order to control the clock frequency of the clock generator ZTG. The frequency control signal FRS is emitted from the clock adjustment device ZJ via the time integration element IG, whose time constant is designed so as to compensate for the typical propagation time fluctuations that occur in the local area network LAN.

If comparatively major discrepancies occur between the internal clock CLK and the real-time clock RTC in the switching device VE, the clock adjustment device ZJ ~~can~~ preferably can request time information from the switching device VE at shorter time intervals.

In the time intervals between each occasion on which time information is received, the clock frequency of the clock transmitter ZTG is stabilized ~~by means of~~ via the communications data KD1, which ~~is~~ likewise is received via the local area network LAN. The communications data KD1 is, for this purpose, supplied from the receiver device EE to the input of the input buffer store EP. This is in the form of a so-called first-in-first-out store, from which temporarily stored data is read in the same time sequence as that in which it was stored. A first-in-first-out store or memory is also often referred to as a "FIFO". The communications data KD1 that has been temporarily stored in the input buffer store EP is read from this buffer store on the basis of the bit clock BT supplied from the clock transmitter ZTG, and is supplied to the DECT radio section DECT. Finally, from there, the communications data KD1 is transmitted without wires to the mobile terminal EG1.

As a rule, communications data and, in particular, voice data is transmitted from a switching device to a terminal at a constant data rate, which is based strictly on the clock in the switching device. Despite any propagation time fluctuations to which such communications data which is transmitted at a constant data rate may be subject, this communications data arrives at the receiver at the same data rate, at least when averaged over time. The time average of the data rate from the received communications data is thus used to synchronize a receiver of such communications data with the clock in the transmitter.

In the present exemplary embodiment, communications data KD1, KD2 is transmitted from the switching device VE at a constant data rate and is used by the base stations BS1, BS2 to stabilize the clock frequency of its own clock transmitter ZTG during the time intervals between individual checks of the time information. For this purpose, in the base station BS1, the present filling level of the input buffer store EP, ~~that is to say~~ or the limit up to which the input buffer store EP is filled with communications data KD1, is recorded at regular time intervals~~,~~ and is transmitted in the form of filling level information FI to the frequency controller FS. The frequency controller FS uses the filling level information FI to form a frequency control signal FRS, which is emitted via an integration element IG, and is combined with the frequency control signal formed by the clock adjustment device ZJ in order to control the clock frequency of the clock transmitter ZTG. The time constant of the integration element IG in the frequency controller FS is designed so as to compensate for the typical propagation time fluctuations of the communications data KD1 which occur in the local area network LAN. For example, the integration elements IG in the frequency controller FS and in the clock adjustment device ZJ may be in the form of a digital circuit~~,~~ in order to form sliding mean values. If the filling level of the input buffer store EP is greater than average, the frequency controller FS forms a frequency control signal FRS in order to increase the clock frequency of the clock generator ZTG, while, if the filling level of the input buffer store EP is below average, it forms a frequency control signal in order to reduce the clock frequency. The frequency control signals FRS emitted from the clock adjustment device ZJ and from the frequency controller FS ~~can~~ each can be combined with predetermined weighting factors before being supplied to the clock transmitter ZTG. In this case, the frequency control signal FRS formed by the clock adjustment device ZJ is preferably given a higher weighting than that formed by the frequency controller FS. The additional stabilization of the clock frequency of the clock transmitter ZTG on the basis of the filling level of the input buffer store EP also allows a relatively low-cost crystal generator without any complex temperature stabilization to be used as the clock

transmitter ZTG, in order to ensure synchronization even if the time intervals between individual time checks are comparatively long.

Although the transmission of the time information ZI1, ZI2 and of the communications data KD1, KD2 via the local area network LAN is not time-transparent, the present invention allows adjacent base stations BS1 and BS2 to be synchronized with sufficient accuracy for seamless handover processes. The high synchronization accuracy is assisted, in particular, by the fact that both the propagation times and the propagation time fluctuations of time information ZI1, ZI2 and communications data KD1, KD2 differ only slightly for adjacent base stations.

In the present exemplary embodiment, the synchronization accuracy is also increased by the use of a number of frequency control mechanisms, and the compensation for propagation time fluctuations ~~by means of~~ via the integration elements IG.

In order to ensure the synchronization accuracy between the base stations BS1 and BS2 which is required for a seamless handover, even in relatively large local area networks LAN, network elements of the local area network LAN, such as repeaters and/or routers, are arranged such that the respective number of network elements connected between the switching device VE and the respective base station BS1 or BS2, and connected between the base station BS1 and BS2, is not greater than a respectively predetermined number.

~~Patent claims~~

Although the present invention has been described with reference to specific embodiments, those of skill in the art will recognize that changes may be made thereto without departing from the spirit and scope of the invention as set forth in the hereafter appended claims.

ABSTRACT OF THE DISCLOSURE

Method and system ~~arrangement~~ for synchronization of base stations in a mobile communications network, ~~For synchronization of base stations (BS1, BS2),~~ in particular for the purpose of a seamless handover, time information ~~(ZI1, ZI2)~~ is transmitted, - possibly on request, - to the base stations ~~(BS1, BS2)~~ from a time information server ~~(VE)~~ via a local area network ~~(LAN)~~. Since base stations ~~(BS1, BS2)~~ which are involved in a seamless handover are generally adjacent, and the respective propagation times and/or propagation time fluctuations of time information ~~(ZI1, ZI2)~~ differ only slightly in the local area network ~~(LAN)~~ between the time information server ~~(VE)~~ and the base station when the base stations are adjacent, ~~the invention allows high~~ highly accurate synchronization ~~to~~ may be achieved, especially for a seamless handover.

~~Figure 1~~

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Description

Method and arrangement for synchronization of base stations in a mobile communications network

In many communications systems, terminals which may be used for different purposes, for example for transmitting voice, video, fax, multimedia, information, text, program and/or measurement data, are increasingly being connected without the use of wires. A connection to such mobile terminals is normally produced via so-called base stations which are connected to a communications network and can be connected to the mobile terminals via an air interface. In the following text, the expression mobile terminals should also be understood as meaning so-called cordless terminals.

User data is generally interchanged via the air interface between a mobile terminal and a base station within time frames which are predetermined by a clock, and which are also referred to in the following text as radio time frames.

The area around a base station in which a wire-free connection of predetermined quality can be set up between a mobile terminal and this base station is also referred to as the radio cell of this base station. In order to supply a larger area with connection capabilities, a number of base stations are generally distributed over the area to be supplied, such that their radio cells form a radio network covering the entire area. A mobile terminal which is registered in such a radio network can in this case move in any desired way between each of the base stations which are located within radio range in this radio network. The process of a mobile terminal being passed on from a first base station to a second base station while a connection exists is also referred to as a handover. In

general, such a change in the connection profile should take place as far as possible without any perceptible interruption

in the connection. This is also referred to as a seamless handover.

However, to carry out a seamless handover, the base stations involved must be synchronized to one another with respect to the air interface. For example, user data to be transmitted via a DECT air interface is embedded in radio time frames whose starts in the base stations involved in a seamless handover must not differ from one another by more than 2 μs.

In this context, the expression synchronization of base stations should be understood as meaning, in particular, synchronization of radio time frames, on which a user data interchange with mobile terminals is based, from different base stations.

Laid-open Specification WO 96/38990 discloses a mobile communications system, in which base stations are each connected to a private branch exchange via an S_0 interface in accordance with the ISDN Standard. In this case, a reference clock is transmitted from the private branch exchange to the base stations via the S_0 interface on the physical layer of the transmission protocol that is being used. The clock generators in these base stations are synchronized on the basis of the reference clock, which is received in the same way by all the base stations.

With regard to the increasing networking of communications systems, increasing integration of voice and data services, and increasing use of complex service features by mobile terminals, it is, however, being found that the connection of base stations via S_0 interfaces is too inflexible. The lack of flexibility is a result, in particular, of the transmission of the reference clock in the physical layer of the transmission protocol that is being used, since continuous layer 1 connections between the private

branch exchange system and the base stations are required for this purpose.

One object of the present invention is to specify a method which is more flexible than the prior art for synchronization of base stations in a mobile communications network, in particular for the purpose of a seamless handover. Another object is to specify an arrangement for implementing the method.

This object is achieved by a method having the features of patent claim 1, and by an arrangement having the features of patent claim 15.

Advantageous embodiments and developments of the invention are specified in the dependent claims.

In order to synchronize base stations in a mobile communications network with respect to their air interface, time information is transmitted to the base stations via a local area network, for example from a time information server. These base stations are synchronized to one another by each aligning their own time measure to time information that is received.

The local area network, which is frequently also referred to as a LAN, can be implemented in many ways, for example in the form of Ethernet, Token Ring, Token Bus or FDDI. The invention allows base stations to be synchronized with little effort, even in complex mobile communications networks. In particular, base stations can easily be integrated in local computer networks, in which case an existing network infrastructure can be used for synchronization. A connection from base stations in a mobile communications network to a local area network is particularly advantageous with respect to increasing integration of voice and data communication, as well.

One major aspect of the invention is the fact that transmission of time information via a local area network is particularly highly suitable for synchronization of base stations for the purpose of the seamless handover. Since only mutually adjacent base stations are essentially involved in a handover process, only the radio time frames of adjacent base stations need be synchronized to one another with high accuracy at the time of the handover, as well. The invention now makes it possible to achieve a high level of synchronization accuracy especially for mutually adjacent base stations, since, in the case of adjacent base stations, both the propagation times of time information to the respective base station and the propagation time fluctuations differ only slightly.

According to one advantageous embodiment of the invention, the clock transmitter in a base station can be adjusted by readjusting its clock frequency and/or phase. In order to avoid abrupt changes in the clock frequency and/or phase, an appropriate control signal can be passed via an integration element to the clock transmitter. As an alternative to this, a clock transmitter error can also be corrected by inserting or omitting clock pulses.

According to one advantageous development of the invention, time information can be requested by a base station via the local area network from a time information server. The request can in this case preferably be made using known network protocols, such as the so-called network time protocol (NTP) or the so-called digital time synchronization protocol (DTSS).

In order to improve the accuracy of the time information which is obtained, the time difference between the request for and the reception of time information can be measured, in order to determine from this an estimated value for the propagation time of the

time information from the time information server to the relevant base station.

On the assumption that the propagation time of the request approximately matches the propagation time of the time information, the propagation time of the time information is half the measured time difference. The accuracy of the estimated value for the propagation time of time information can be improved by determining the estimated value from a mean value of time differences measured over a number of requests, or of variables derived from them. This makes it possible to compensate for propagation time fluctuations in the data transmitted via the local area network. The determined estimated value for the propagation time of time information can be taken into account to correct the adjustment of the clock transmitter.

The frequency with which time information is requested by a base station may depend on various criteria. For example on the accuracy of the clock transmitter in the base station, on the variation range of the time differences measured between a request for and reception of time information, and/or on the magnitude of any clock transmitter error that was found in a previous adjustment of the clock transmitter. The time information can preferably be requested more frequently the less the accuracy of the clock transmitter and the greater the variation range of the measured time differences and the error that is found in the clock transmitter.

According to a further advantageous development of the invention, a data stream which is received via the local area network can be buffered in an input buffer store operating on the first-in-first-out principle (FIFO), from which data elements of the data stream are read for further processing using a clock cycle governed by the clock transmitter. The clock frequency of the clock transmitter can then be readjusted on the basis of the filling level of the input buffer store.

Subject to the precondition that the data stream received via the local area network is transmitted, at least when averaged over time, at a data rate which is predetermined by a clock transmitter

in the data stream transmitter, the clock transmitter in the base station can thus be synchronized to the clock transmitter in the data stream transmitter, when averaged over time. In order to compensate for short-term propagation time fluctuations of data elements in the data stream, a clock frequency control signal, which is derived from the filling level, can be passed to the clock tránsmitter via an integration element.

A data stream of communications data which is received via the local area network and is to be transmitted to a mobile terminal, such as voice data, can preferably be used for clock frequency control. Since communications data and, in particular, voice data is transmitted frequently in an existing connection at a transmission rate which is maintained accurately and is based on the time clock for the transmitter of the communications data, the clock frequency of the clock transmitter can be stabilized particularly accurately on the basis of received communications data or voice data.

An exemplary embodiment of the invention will be explained in more detail in the following text with reference to the drawing.

In this case, in each case illustrated schematically:

Figure 1 shows a mobile communications network with two base stations which are connected to a switching device via a local area network, and

Figure 2 shows a detailed illustration of one of the base stations which are connected to the local area network.

Figure 1 illustrates, schematically, a mobile communications network with a switching device VE, which is connected to a landline network FN, and with two base stations BS1 and BS2, which are coupled to the switching device VE via a local area network LAN. In the present exemplary embodiment, the base stations BS1 and BS2 are in the form of DECT base stations (Digital European Cordless Telephone). While

a wire-free connection is set up via the base station BS1 to a mobile terminal EG1, a wire-free connection to a mobile terminal EG2 runs via the base station BS2. The mobile terminal EG1 is also connected by radio to the base station BS2, which is adjacent to the base station BS1, in order to prepare for a change in the connection routing (handover) from the base station BS1 to the base station BS2. The radio links are each indicated by a stylized lightning flash in the present exemplary embodiment.

The switching device VE is connected to the landline network FN via a landline network interface FNS, and is connected to the local area network LAN via a network interface NS. The switching device VE also has a central controller ZS, which is connected to the network interfaces FNS and NS and has a real-time clock RTC, and also has a GPS (Global Positioning System) receiver GPS for receiving world time information from a satellite SAT. The real-time clock RTC is adjusted by the GPS receiver by the transmission of up-to-date time information ZI at regular time intervals.

The local area network LAN which may, for example, be an Ethernet, Token Ring, Token Bus or FDDI, supports packet-oriented data transmission. In addition to communications devices, data processing devices (not shown) can also be connected to the local area network LAN. In the present exemplary embodiment, the local area network LAN is used for transmitting not only all the communications data but also all the control data between the switching device VE and the base stations BS1 and BS2. Since a local area network can be extended very easily and can very easily have further communications and/or data processing devices added to it, a mobile communications network implemented in such a way can be matched very flexibly to widely differing requirements.

In the present exemplary embodiment, communications data KD1 and KD2, for example voice data, is transmitted from the landline network FN

to the switching device VE via connections which lead from the landline network FN to the mobile terminals EG1 and EG2. In this switching device VE, the communications data KD1, KD2 which has been received via the landline network interface FNS is in each case provided by the central controller ZS with address information to identify the base station BS1 or BS2 in the local area network LAN, and is transmitted via the network interface NS to the local area network LAN. The base stations BS1 and BS2 receive from the local area network LAN the respective communications data addressed to them themselves; that is to say the base station BS1 receives the communications data KD1, and the base station BS2 receives the communications data KD2. The base stations BS1 and BS2, respectively, then transmit the received communications data KD1 and KD2, respectively, embedded in DECT time frames, without wires to the mobile terminals EG1 and EG2, respectively.

In order to allow a seamless handover during an existing connection for a mobile terminal, in this case EG1, between two adjacent base stations, in this case BS1 and BS2, these base stations BS1 and BS2 have to maintain a frequency accuracy of $\pm 10^{-3}\%$ in accordance with the DECT Standard. Furthermore, the DECT time frames, on which data transmission to a mobile terminal is based, in the base stations BS1 and BS2 must be synchronized to one another with a tolerance of 2 µs. In order to synchronize the base stations BS1 and BS2 to one another, each of the base stations BS1 and BS2 is synchronized in its own right to a central clock transmitter device, in this case the real-time clock RTC in the switching device VE. The synchronization process is in this case carried out via the local area network LAN. For this purpose, the base stations BS1 and BS2 each transmit a time request message ZA1 or ZA2, respectively, for example in accordance with the so-called network time protocol (NTP), via the local

area network LAN to the switching device VE. The received time request messages ZA1, ZA2 in each case cause the switching device VE to request up-to-date time information ZI1 or ZI2, respectively, from the real-time clock RTC, and then to transmit it, together with address information identifying the respective base station BS1 or BS2, via the local area network LAN

to the respectively addressed base station BS1 or BS2. The switching device VE thus carries out the function of a time information server in the local area network LAN.

Figure 2 shows a more detailed illustration of the base station BS1. The base station BS1, which is coupled via a network interface NS to the local area network LAN, has, as further functional components, a receiving device EE, an input buffer store EP, a clock transmitter ZTG, a clock adjustment device ZJ, a frequency controller FS, and a DECT radio section DECT. The clock adjustment device ZJ itself has an internal clock CLK, a propagation time determination device LB, a propagation time correction device LK and an integration element IG. For reasons of clarity, the illustration does not show the other functional components of the base station BS1 which do not contribute directly to understanding of the invention. The illustrated functional components may each also be in the form of software modules, running on a system processor in the base station BS1.

The clock transmitter ZTG thus provides not only a bit clock BT but also a frame clock RT synchronized to it. The frequency of the bit clock BT, and hence the frequency of the frame clock RT, are in this case controllable. While the bit clock BT represents the elementary time measure for the control processes in the base station BS1, the frame clock RT provides a time measure for the DECT time frames. In the present exemplary embodiment, the bit clock BT is supplied to the clock adjustment device ZJ, to the input buffer store EP and to the DECT radio section DECT. In the clock adjustment device ZJ, the bit clock BT is used in particular for supplying timing pulses to the internal clock CLK. The DECT radio section DECT is supplied not only with the bit clock BT but also with the frame

clock RT, which governs the time pattern for the DECT time frames transmitted by the DECT radio section DECT.

In order to synchronize the clock transmitter ZTG to the time measure in the switching device VE, the clock adjustment device ZJ transmits the time request message ZA1 via the network interface NS and via the local area network LAN to the switching device VE. The time at which the time request message ZA1 is transmitted is in this case registered and stored by means of the internal clock CLK. The time request message ZA1 causes the switching device VE, as already mentioned above, to transmit the time information ZI1 via the local area network LAN to the base station BS1. The time information ZI1 is passed on from the network interface NS for the base station BS1 to the receiving device EE, where the time information ZI1 is extracted from a data stream which is received via the local area network LAN and also contains the communications data KD1. The extracted time information ZI1 is passed on from the receiving device EE to the clock adjustment device ZJ, which uses the internal clock CLK to determine the time at which the time information ZI1 is received, and evaluates the time information content of the time information ZI1. The propagation time determination device LB then estimates the propagation time of the time information ZI1 in the local area network LAN as being half the time difference between the time at which it was found that the time information ZI1 was received and the stored transmission time of the time request message ZA1.

In order to improve the accuracy of determining the propagation time and to compensate for short-term propagation time fluctuations, the value which is obtained for the propagation time is averaged together with previously determined values for the propagation time. A sliding average is preferably determined. If required, a time stamp relating to the time information ZI1 can also be included in the propagation time determination process.

The time indicated by the time information content of the time information ZI1 is then corrected by the propagation time correction device LK for the previously determined propagation

time of the time information ZI1. The corrected time is then compared with the time indicated by the internal clock CLK for the time at which the time information ZI1 was received. Depending on the comparison result, a frequency control signal FRS is then formed in order to control the clock frequency of the clock generator ZTG. The frequency control signal FRS is emitted from the clock adjustment device ZJ via the time integration element IG, whose time constant is designed so as to compensate for the typical propagation time fluctuations that occur in the local area network LAN.

If comparatively major discrepancies occur between the internal clock CLK and the real-time clock RTC in the switching device VE, the clock adjustment device ZJ can preferably request time information from the switching device VE at shorter time intervals.

In the time intervals between each occasion on which time information is received, the clock frequency of the clock transmitter ZTG is stabilized by means of the communications data KD1, which is likewise received via the local area network LAN. The communications data KD1 is for this purpose supplied from the receiver device EE to the input of the input buffer store EP. This is in the form of a so-called first-in-first-out store, from which temporarily stored data is read in the same time sequence as that in which it was stored. A first-in-first-out store or memory is also often referred to as a "FIFO". The communications data KD1 that has been temporarily stored in the input buffer store EP is read from this buffer store on the basis of the bit clock BT supplied from the clock transmitter ZTG, and is supplied to the DECT radio section DECT. Finally, from there, the communications data KD1 is transmitted without wires to the mobile terminal EG1.

As a rule, communications data and, in particular, voice data is transmitted from a switching device to a

terminal at a constant data rate, which is based strictly on the clock in the switching device. Despite any propagation time fluctuations to which such communications data which is transmitted at a constant data rate may be subject, this communications data arrives at the receiver at the same data rate, at least when averaged over time. The time average of the data rate from the received communications data is thus used to synchronize a receiver of such communications data with the clock in the transmitter.

In the present exemplary embodiment, communications data KD1, KD2 is transmitted from the switching device VE at a constant data rate and is used by the base stations BS1, BS2 to stabilize the clock frequency of its own clock transmitter ZTG during the time intervals between individual checks of the time information. For this purpose, in the base station BS1, the present filling level of the input buffer store EP, that is to say the limit up to which the input buffer store EP is filled with communications data KD1, is recorded at regular time intervals, and is transmitted in the form of filling level information FI to the frequency controller FS. The frequency controller FS uses the filling level information FI to form a frequency control signal FRS, which is emitted via an integration element IG, and is combined with the frequency control signal formed by the clock adjustment device ZJ in order to control the clock frequency of the clock transmitter ZTG. The time constant of the integration element IG in the frequency controller FS is designed so as to compensate for the typical propagation time fluctuations of the communications data KD1 which occur in the local area network LAN. For example, the integration elements IG in the frequency controller FS and in the clock adjustment device ZJ may be in the form of a digital circuit, in order to form sliding mean values. If the filling level of the input buffer store EP is greater than average, the frequency

controller FS forms a frequency control signal FRS in order to increase the clock frequency of the clock generator ZTG, while, if the filling level of the

input buffer store EP is below average, it forms a frequency control signal in order to reduce the clock frequency. The frequency control signals FRS emitted from the clock adjustment device ZJ and from the frequency controller FS can each be combined with predetermined weighting factors before being supplied to the clock transmitter ZTG. In this case, the frequency control signal FRS formed by the clock adjustment device ZJ is preferably given a higher weighting than that formed by the frequency controller FS. The additional stabilization of the clock frequency of the clock transmitter ZTG on the basis of the filling level of the input buffer store EP also allows a relatively low-cost crystal generator without any complex temperature stabilization to be used as the clock transmitter ZTG, in order to ensure synchronization even if the time intervals between individual time checks are comparatively long.

Although the transmission of the time information ZI1, ZI2 and of the communications data KD1, KD2 via the local area network LAN is not time-transparent, the invention allows adjacent base stations BS1 and BS2 to be synchronized with sufficient accuracy for seamless handover processes. The high synchronization accuracy is assisted, in particular, by the fact that both the propagation times and the propagation time fluctuations of time information ZI1, ZI2 and communications data KD1, KD2 differ only slightly for adjacent base stations.

In the present exemplary embodiment, the synchronization accuracy is also increased by the use of a number of frequency control mechanisms, and the compensation for propagation time fluctuations by means of the integration elements IG.

In order to ensure the synchronization accuracy between the base stations BS1 and BS2 which is required for a

seamless handover, even in relatively large local area networks LAN, network elements of the local area network LAN, such as repeaters and/or routers, are arranged such that the respective

number of network elements connected between the switching device VE and the respective base station BS1 or BS2, and connected between the base station BS1 and BS2, is not greater than a respectively predetermined number.

Patent claims

1) A method for synchronization of base stations (BS1, BS2) in a mobile communications network, in which

a) time information (ZI1, ZI2) is transmitted via a local area network (LAN) to the base stations (BS1, BS2),

b) a clock transmitter (ZTG) for a respective base station (BS1, BS2) which receives time information (ZI1, ZI2) is adjusted on the basis of the reception time and on the time information content of the time information (ZI1, ZI2) and

c) the transmission of functional sequences, which relate to radio time frames, to the respective base station (BS1, BS2) is controlled by signals (RT, BT) from the clock transmitter (ZTG).

2) The method as claimed in claim 1, characterized in that the clock transmitter (ZTG) of a base station (BS1, BS2) is adjusted by readjusting its clock frequency and/or phase.

3) The method as claimed in claim 1 or 2, characterized in that the clock transmitter (ZTG) of a base station (BS1, BS2) is adjusted by omitting or inserting clock pulses.

4) The method as claimed in one of the preceding claims, characterized in that time information (ZI1, ZI2) is requested by a base station (BS1, BS2) via the local area network (LAN) from a time information server (VE).

5) The method as claimed in claim 4,

characterized
in that the request for and transmission of the time information (ZI1,

ZI2) are carried out in accordance with a standardized network protocol.

6) The method as claimed in claim 4 or 5, characterized in that the time difference between the request for and reception of the time information (ZI1, ZI2) is measured, an estimated value for the propagation time of the time information (ZI1, ZI2) from the time information server (VE) to the base station (BS1, BS2) is determined from the measured time difference, and the clock transmitter (ZTG) is adjusted using the determined estimated value of propagation time of the time information (ZI1, ZI2).

7) The method as claimed in claim 6, characterized in that the time difference is measured by means of the clock transmitter (ZTG) in the base station (BS1, BS2).

8) The method as claimed in claim 6 or 7, characterized in that averaging is carried out over a number of measured time differences, or variables defined from such differences, in order to determine the estimated value of propagation time of time information (ZI1, ZI2).

9) The method as claimed in one of claims 4 to 8, characterized in that time information (ZI1, ZI2) is requested by a base station (BS1, BS2) at regular time intervals via the local area network (LAN).

10) The method as claimed in one of claims 6 to 8, characterized

in that time information (ZI1, ZI2) is requested by a base station (BS1, BS2) via the local area network (LAN) at time intervals which are dependent on the severity with which the

measured time differences vary.

11) The method as claimed in one of the preceding claims, characterized in that a data stream (KD1, KD2), which is received via the local area network (LAN) from a base station (BS1, BS2) is temporarily stored in an input buffer store (EP) which operates on the first-in-first-out principle, from which data elements of the data stream (KD1, KD2) are read for further processing using a clock cycle governed by the clock transmitter (ZTG), in that the filling level of the input buffer store (EP) is recorded, and in that the clock frequency of the clock transmitter (ZTG) is readjusted on the basis of the recorded filling level.

12) The method as claimed in claim 11, characterized in that the data stream to be temporarily stored in the input buffer store (EP) comprises communications data (KD1, KD2) which is being received via the local area network (LAN) and is to be transmitted to a mobile terminal (EG1, EG2).

13) The method as claimed in claim 11 or 12, characterized in that the adjustment of the clock transmitter (ZTG) on the basis of received time information (ZI1, ZI2) is given priority over the adjustment based on the recorded filling level.

14) The method as claimed in one of the preceding claims, characterized in that a base station (BS1, BS2) receives time information from a number of time information servers

via the local area network (LAN), and uses this for adjustment of the clock transmitter (ZTG).

15) An arrangement for synchronization of base stations (BS1, BS2) in a mobile communications network, in which the base stations (BS1, BS2) are coupled to a local area network (LAN), and each have means for synchronization of a time measure for a respective base station on the basis of time information (ZI1, ZI2) which is transmitted via the local area network (LAN).

16) The arrangement as claimed in claim 15, characterized by

a time information server (VE), which is coupled to the local area network, having a timer device (RTC) for transmitting time information (ZI1, ZI2) via the local area network (LAN) to the base stations (BS1, BS2), with the base stations (BS1, BS2) each having

- a clock transmitter (ZTG),
- a time information receiving device (EE) for extracting time information (ZI1, ZI2) from a data stream which has been received via the local area network (LAN),
- a clock adjustment device (ZJ) for adjusting the clock transmitter (ZTG) on the basis of the reception time and the time information content of received time information (ZI1, ZI2) and
- a control device (DECT) for controlling the timing of functional sequences, which relate to the transmission of radio time frames, on the basis of signals (RT, BT) from the clock transmitter (ZTG).

17) The arrangement as claimed in claim 16, characterized

in that the time information server (VE) has a satellite navigation receiver device (GPS) for receiving world time information and for presetting a time measure for the time information server (VE) on the basis of the received world time information.

18) The arrangement as claimed in clam 16 or 17, characterized in that the base stations (BS1, BS2) each have a time checking device (ZJ) for requesting time information (ZI1, ZI2) via the local area network (LAN).

19) The arrangement as claimed in claim 18, characterized in that the base stations (BS1, BS2) each have a time measurement device (CLK) for measuring the time difference between a request for and reception of time information (ZI1, ZI2), a propagation time determination device (LB) for determining an estimated value of the propagation time of the time information (ZI1, ZI2) from the time information server (VE) to the respective base station (BS1, BS2) on the basis of the measured time difference, and
a propagation time correction device (LK) for correcting the time information (ZI1, ZI2) for its estimated propagation time.

20) The arrangement as claimed in claim 19, characterized in that the time measurement device (CLK) is in the form of a counter which counts signals (BT) from the clock transmitter (ZTG).

21) The arrangement as claimed in one of claims 16 to 20, characterized in that the base stations (BS1, BS2) each have an input buffer store (EP) for temporarily storing a data stream (KD1, KD2) which is received via the local area network (LAN),
a filling level recording device for recording the filling level of the input buffer store (EP), as well as

a clock frequency control device (FS) for readjusting the clock frequency of the clock transmitter (ZTG) as a function of the recorded filling level.

22) The arrangement as claimed in one of claims 16 to 21,
characterized
in that the base stations (BS1, BS2) each have a PLL circuit for controlling the clock frequency of the clock transmitter (ZTG).

23) The arrangement as claimed in one of claims 15 to 22,
characterized in that the base stations (BS1, BS2) are adjacent in the local area network (LAN).

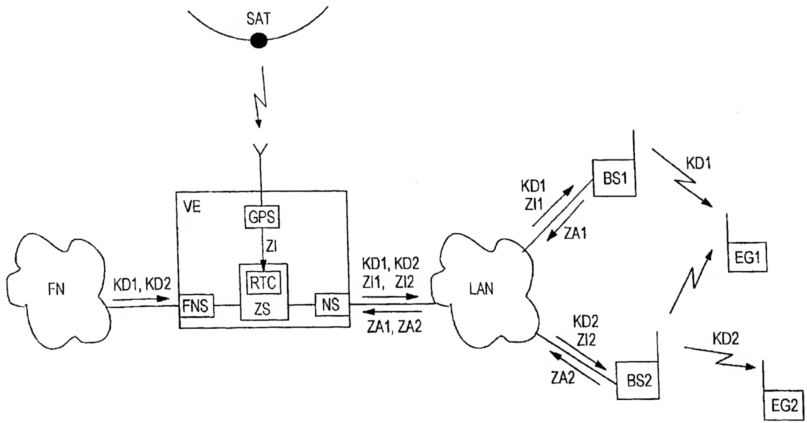
Abstract

Method and arrangement for synchronization of base stations in a mobile communications network

For synchronization of base stations (BS1, BS2), in particular for the purpose of a seamless handover, time information (ZI1, ZI2) is transmitted - possibly on request - to the base stations (BS1, BS2) from a time information server (VE) via a local area network (LAN). Since base stations (BS1, BS2) which are involved in a seamless handover are generally adjacent, and the respective propagation times and/or propagation time fluctuations of time information (ZI1, ZI2) differ only slightly in the local area network (LAN) between the time information server (VE) and the base station when the base stations are adjacent, the invention allows high accurate synchronization to be achieved, especially for a seamless handover.

Figure 1

FIG 1


SAT
VE
GPS
ZI
RTC
ZS
FNS
NS
FN
KD1, KD2
KD1, KD2
ZI1, ZI2
ZA1, ZA2
LAN
KD1
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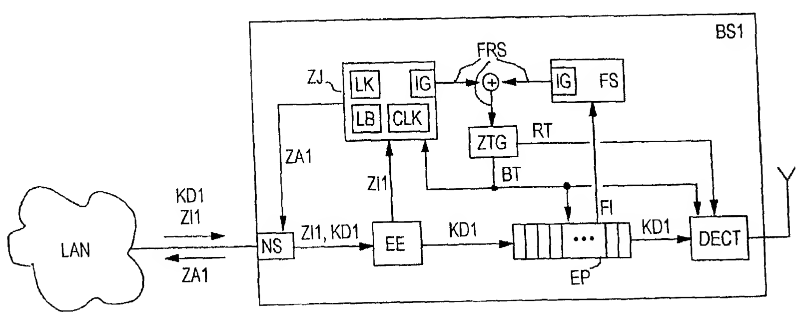
ZA1
KD2
ZI2
ZA2
BS1
BS2
KD1
KD2
EG1
EG2

FIG 2


BS1
ZJ
LK
IG
LB
CLK
FRS
IG
FS
ZTG
RT
BT
ZA1
ZI1
FI
KD1
ZI1
LAN
NS
ZI1, KD1
EE
KD1
KD1
DECT
EP
ZA1

New patent claims

1) A method for synchronization of base stations (BS1, BS2) in a mobile communications network, in which

a) time information (ZI1, ZI2) is transmitted via a packet-oriented local area network (LAN) to the base stations (BS1, BS2),

b) a clock transmitter (ZTG) for a respective base station (BS1, BS2) which receives time information (ZI1, ZI2) is adjusted on the basis of the reception time and on the time information content of the time information (ZI1, ZI2) and

c) the transmission of functional sequences, which relate to radio time frames, to the respective base station (BS1, BS2) is controlled by signals (RT, BT) from the clock transmitter (ZTG).

15) An arrangement for synchronization of base stations (BS1, BS2) in a mobile communications network, in which the base stations (BS1, BS2) are coupled to a packet-oriented local area network (LAN), and each have means for synchronization of a time measure for a respective base station on the basis of time information (ZI1, ZI2) which is transmitted via the local area network (LAN).

FIG 1

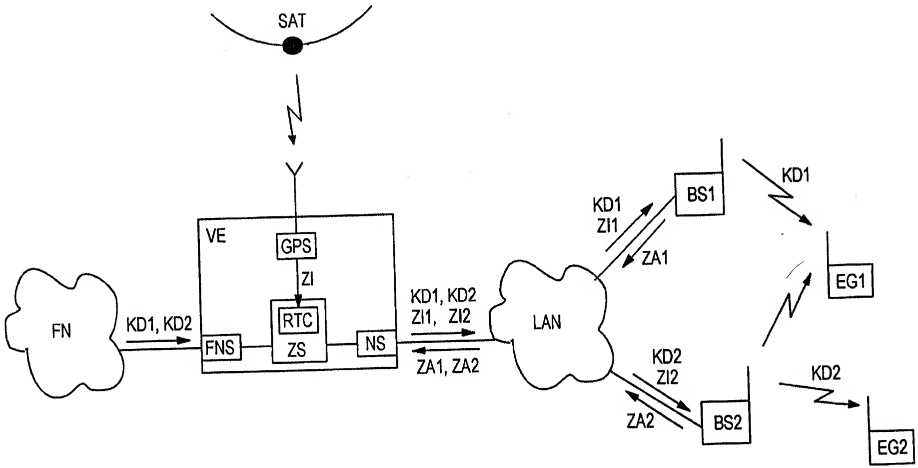
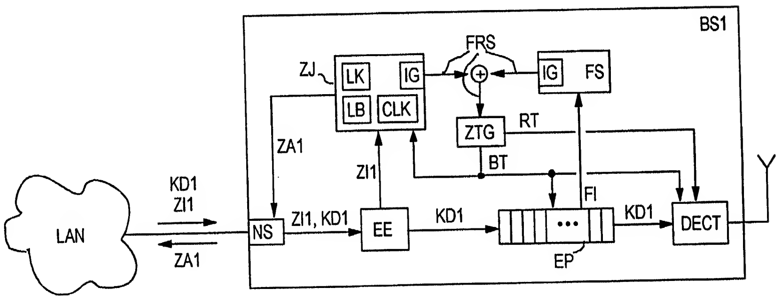

SAT
VE
GPS
ZI
RTC
ZS
FNS
NS
FN
KD1, KD2
KD1, KD2
ZI1, ZI2
ZA1, ZA2
LAN
KD1
ZI1
ZA1
KD2
ZI2
ZA2
BS1
BS2
KD1
KD2
EG1
EG2

FIG 2


BS1
LAN
KD1
ZI1
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NS
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IG
LB
CLK
FRS
IG
FS
ZTG
RT
BT
KD1
FI
EP
KD1
DECT

Declaration and Power of Attorney For Patent Application
Erklärung Für Patentanmeldungen Mit Vollmacht
German Language Declaration

Als nachstehend benannter Erfinder erkläre ich hiermit an Eides Statt:

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Verfahren und Anordnung zum Synchronisieren von Basisstationen eines mobilen Kommunikationsnetzes

deren Beschreibung

(zutreffendes ankreuzen)
☐ hier beigefügt ist.
☒ am 07.09.2000 als
PCT internationale Anmeldung
PCT Anmeldungsnummer PCT/DE00/03106
eingereicht wurde und am ______
abgeändert wurde (falls tatsächlich abgeändert).

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As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name,

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

Method and device for synchronizing base stations of a mobile communications network

the specification of which

(check one)
☐ is attached hereto.
☒ was filed on 07.09.2000 as
PCT international application
PCT Application No. PCT/DE00/03106
and was amended on ______
(if applicable)

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, §1.56(a).

I hereby claim foreign priority benefits under Title 35, United States Code, §119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

German Language Declaration

Prior foreign appplications
Priorität beansprucht

Priority Claimed

19943778.5 (Number) (Nummer)	DE (Country) (Land)	13.09.1999 (Day Month Year Filed) (Tag Monat Jahr eingereicht)	☒ Yes Ja	☐ No Nein
(Number) (Nummer)	(Country) (Land)	(Day Month Year Filed) (Tag Monat Jahr eingereicht)	☐ Yes Ja	☐ No Nein
(Number) (Nummer)	(Country) (Land)	(Day Month Year Filed) (Tag Monat Jahr eingereicht)	☐ Yes Ja	☐ No Nein

Ich beanspruche hiermit gemäss Absatz 35 der Zivilprozessordnung der Vereinigten Staaten, Paragraph 120, den Vorzug aller unten aufgeführten Anmeldungen und falls der Gegenstand aus jedem Anspruch dieser Anmeldung nicht in einer früheren amerikanischen Patentanmeldung laut dem ersten Paragraphen des Absatzes 35 der Zivilprozeßordnung der Vereinigten Staaten, Paragraph 122 offenbart ist, erkenne ich gemäss Absatz 37, Bundesgesetzbuch, Paragraph 1.56(a) meine Pflicht zur Offenbarung von Informationen an, die zwischen dem Anmeldedatum der früheren Anmeldung und dem nationalen oder PCT internationalen Anmeldedatum dieser Anmeldung bekannt geworden sind.

I hereby claim the benefit under Title 35. United States Code. §120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, §122, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, §1.56(a) which occured between the filing date of the prior application and the national or PCT international filing date of this application.

PCT/DE00/03106 (Application Serial No.) (Anmeldeseriennummer)	07.09.2000 (Filing Date D, M, Y) (Anmeldedatum T, M, J)	anhängig (Status) (patentiert, anhängig, aufgegeben)	pending (Status) (patented, pending, abandoned)
(Application Serial No.) (Anmeldeseriennummer)	(Filing Date D,M,Y) (Anmeldedatum T, M; J)	(Status) (patentiert, anhängig, aufgeben)	(Status) (patented, pending, abandoned)

Ich erkläre hiermit, dass alle von mir in der vorliegenden Erklärung gemachten Angaben nach meinem besten Wissen und Gewissen der vollen Wahrheit entsprechen, und dass ich diese eidesstattliche Erklärung in Kenntnis dessen abgebe, dass wissentlich und vorsätzlich falsche Angaben gemäss Paragraph 1001, Absatz 18 der Zivilprozessordnung der Vereinigten Staaten von Amerika mit Geldstrafe belegt und/oder Gefängnis bestraft werden koennen, und dass derartig wissentlich und vorsätzlich falsche Angaben die Gültigkeit der vorliegenden Patentanmeldung oder eines darauf erteilten Patentes gefährden können.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true, and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

German Language Declaration

VERTRETUNGSVOLLMACHT: Als benannter Erfinder beauftrage ich hiermit den nachstehend benannten Patentanwalt (oder die nachstehend benannten Patentanwälte) und/oder Patent-Agenten mit der Verfolgung der vorliegenden Patentanmeldung sowie mit der Abwicklung aller damit verbundenen Geschäfte vor dem Patent- und Warenzeichenamt: *(Name und Registrationsnummer anführen)*

Customer No. 29177

POWER OF ATTORNEY: As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith: *(list name and registration number)*

29177 And I hereby appoint

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Unterschrift des Erfinders / Datum	Second Inventor's signature / Date
Wohnsitz	Residence
Staatsangehörigkeit	Citizenship
Postanschrift	Post Office Address

(Bitte entsprechende Informationen und Unterschriften im Falle von dritten und weiteren Miterfindern angeben).

(Supply similar information and signature for third and subsequent joint inventors).